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USATEA REPORT 70-8

ENGINEERING REPORT

PREDICTING HIGH TEMPERATURES INSIDE CARGO CONTAINERS

JUNE 1970

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ABSTRACT

This report summarizes the work in connection with a study on predicting high temperature inside cargo containers and presents, in detail, information on tests conducted at the Tropic Test Center in the Panama Canal Zone. Included are meteorological data provided by the Tropic Test Center, temperature values recorded both on the surface and inside a CONEX container, and photographs of the test area. A comparison is made between recorded values and temperatures calculated by a computer program previously developed by the U.S. Army Transportation Engineering Agency. Computer printouts are included as appendixes.

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I. INTRODUCTION

The purpose of this project was to develop a procedure for predicting the maximum temperature which might be encountered within closed shipping containers, such as the CONEX, on a worldwide basis, for any given time. The initial work resulted in the development of a computer program for calculating the amount of heat generated due to solar radiation on the surfaces of walls or roofs of containers. Details on this computer program are contained in Engineering Research Division, U.S. Army Transportation Engineering Agency, Military Traffic Management and Terminal Service, Fort Eustis, Virginia.

The next step resulted in the development of a computer program to determine the maximum expected temperature inside a closed container subjected to solar radiation. To verify the accuracy of the program and to make necessary adjustments, field tests were conducted at Fort Eustis, Virginia, and Yuma, Arizona, on the temperature rise within a CONEX container left standing in the sun. A comparison was made with temperature values calculated by a previously developed computer program.

The predicted temperatures, when compared with measured values at Fort Eustis and Yuma, were not of sufficient volume to prove the procedure's reliability; therefore, additional field tests were conducted at Fort Clayton, Panama Canal Zone. This report presents the data obtained during the tests, a printout of the adjusted program (Appendix I), and a comparison of the theoretical temperature as predicted by the computer program versus recorded values at Fort Eustis, Virginia; Yuma, Arizona; and Fort Clayton, Panama Canal Zone.

In addition to the above work, considerable research was conducted on reports prepared by other agencies, particularly by Natick Laboratories. Natick Laboratories has prepared hundreds of technical reports on environments, worldwide, since 1942. Reports of interest in connection with this study included:

Occurrence of High Temperatures in Standing Boxcars

Occurrence of High Temperatures in Yuma Storage Dumps

Frequency and Duration of High Temperatures

High Temperatures and Accompanying Humidities in Transit and Short-Term Storage

World Maps of Maximum Hourly Durations of Specified High and Low Temperatures

A summation of extreme temperatures in storage or transit observed or reported in literature is included as Appendix II.

Based on the extensive research conducted in connection with this study, it appears that the climatic design criteria as set forth in AR 705-15, Change 1, Research and Development of Materiel, Operation of Materiel Under Extreme Conditions of Environment, is adequate as regards high temperatures. An excerpt of this regulation is included as Appendix III.

II. OBJECTIVES

1. To obtain the temperature profile of an empty CONEX container left out in the sun in a hot-humid climate, such as Panama.

2. To make necessary adjustments in the computer program and determine the percent error between predicted and recorded maximum inside temperatures for an empty CONEX container located at Fort Eustis, Virginia; Yuma, Arizona; and Fort Clayton, Panama Canal Zone.

III. CONCLUSIONS

1. The percent error between predicted and recorded temperatures at the center of an empty CONEX container at approximately 116 degrees Fahrenheit (°F.) inside were:

Location	Recorded (°F.)	Predicted (°F.)	Pct. Error (%)
Fort Eustis, Va.	116	110.9	-4.4
Yuma, Ariz.	117	123.0	+5.1
Fort Clayton, C. Z.	116	113.8	-1.9

2. The adjusted computer program can be used to predict the expected maximum temperature, with a reasonable degree of accuracy, at the center of an empty CONEX container, and it can be used to estimate the expected maximum temperature at the center of other types of empty containers. However, additional testing will be required to provide positive substantiation of its reliability through the full temperature range in consideration.

3. Based on the overall study, the maximum design temperature value, as directed by AR 705-15, Change 1, for all military materiel, for storage and transit conditions appears reasonable (Appendix III).

IV. RECOMMENDATIONS

1. That data collected on monitoring projects be used, when appropriate, to verify and expand the prediction procedures.

2. That extreme temperatures which may be encountered in transit and storage be reflected in criteria technical bulletins.

3. That additional field tests be conducted at high temperatures (150-160° F.) on CONEX and other type containers both loaded and empty.

V. GENERAL

1. Test Site (9°0' N., 79°35' W.). The Tropic Test Center (TTC) is located in the Fort Clayton area of the Panama Canal Zone. The CONEX container used in the temperature tests was located in the Chiva-Chiva test site about 8 miles from TTC. A meteorological station is located at the site and is capable of recording solar radiation, air temperatures, relative humidity, average wind speed and direction, and amount of rainfall. The entire area is surrounded by a fence, and a guard is posted at the main entrance. Access to the Chiva-Chiva site is by permit only.

During the period of test, 12 January 1970 to 26 January 1970, temperatures during the day were in the high 80's or low 90's and during the night were in the 70's. Large amounts of rain fell during the test, which is considered unusual for this time of year since the dry season for the area takes place from mid-December to May.

During the morning, skies were generally clear, with development of partly cloudy conditions in the late afternoon. The container was located in a clear area in a mild ground depression (Figure 1). During the morning a low hill approximately 1,000 yards to the east blocked the sun and delayed the solar radiation heating process for about 30 minutes. Outside the cleared area, dense vegetation and undergrowth were prevalent (Figure 2).

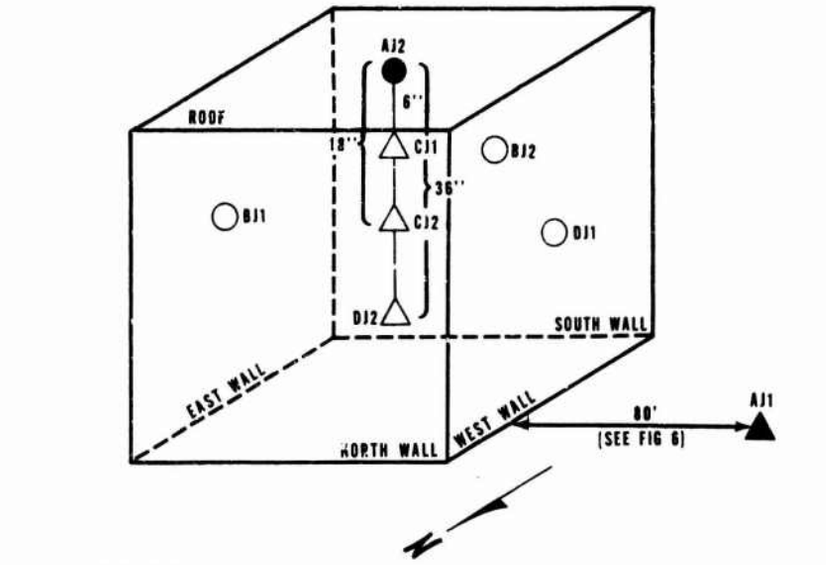
Figure 1. CONEX Located in Slight Ground Depression.

Figure 2. Surrounding Jungle Vegetation.

2. Instrumentation. Temperature chart recorders were used to gather the information. Each recorder was equipped with a weatherproof inclosure, 100 feet of twin cables, and two types of interchangeable probes: a surface-sensing probe and a general-purpose probe. The recorders were capable of recording the range 25° C. to 75° C. (77° F. to 167° F.) and were completely self-contained. Two 6-volt lantern batteries powered each unit for a maximum of 3 weeks of continuous recording. Each

recorder monitored two sensors, and the data were preserved on a pressure-sensitive chart paper which traveled at a rate of 1 inch per hour. The recorders weighed approximately 30 pounds each and measured 12 by 13 by 6 inches overall including the weatherproof inclosure. Meteorological instrumentation at the site provided solar radiation data for an open area vertical, 45° north, 45° south, and jungle vertical. Also provided were hygrothermographs for both the open area and jungle, rain gauge charts for open area and jungle, and wind direction and speed for open area and jungle.

The CONEX container was situated in a relatively clear area with the door of the container facing approximately north. Eight sensors were placed on and around the container, and the recorders were placed in front of the door and in as much shade as possible (Figures 3, 4, 5, and 6).



SENSORS

AJ1-----AIR AMBIENT
AJ2-----ROOF
BJ1-----EAST WALL (INSIDE)
BJ2-----SOUTH WALL
CJ1-----6" UNDER ROOF
CJ2-----18" UNDER ROOF
DJ1-----WEST WALL
DJ2-----36" UNDER ROOF

KEY

● SURFACE PROBE (OUTSIDE)
○ SURFACE PROBE (INSIDE)
▲ AIR TEMPERATURE PROBE (OUTSIDE)
△ AIR TEMPERATURE PROBE (INSIDE)

Figure 3. Sensor Location.

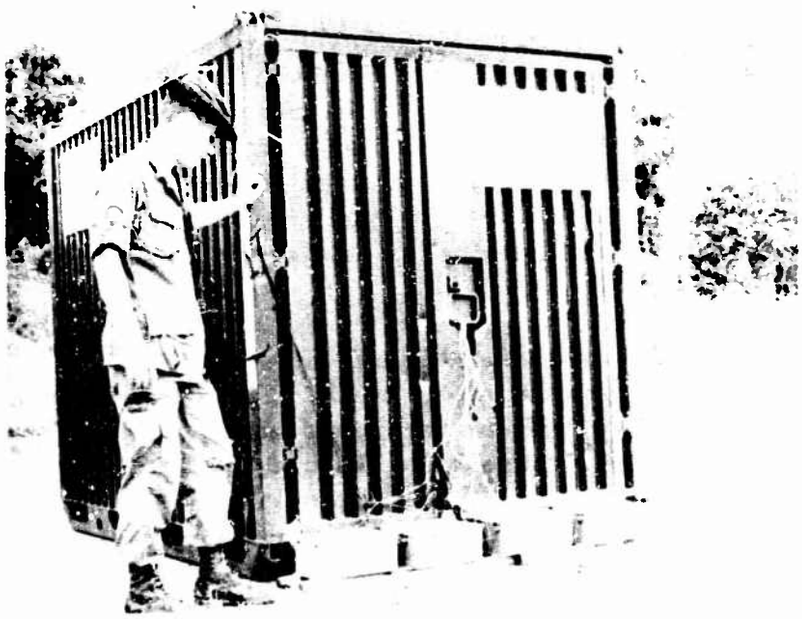


Figure 4. Recorders on Wooden Stakes in Front of CONEX Door.

Figure 5. CONEX Interior With Air Sensors Hanging From Ceiling and Hygrometer on Floor.

Figure 6. Ambient Air Sensor With Solar Radiation Shield Made From Styrofoam Scraps.

3. Itinerary. A general itinerary was used for the test with adjustments to meet unforeseen contingencies:

Day 1 - Travel.
Day 2 - Orientation.
Day 3 - Organize equipment.
Day 4 - Equipment calibration.
Day 5 - Equipment setup.
Day 6 - Trial run, debugging.
Day 7-14 - Record. (At this time a briefing was given to Commanding General of U.S. Army Test and Evaluation Command, MG Isenour.)
Day 15 - Breakdown of equipment and packing. Clear post.
Day 16 - Travel back to continental United States (CONUS) duty station.

4. Analysis. Data gathered at the Chiva-Chiva test site of the Tropic Test Center covered the period from 15 January 1970 to 26 January 1970. The data at this location did not have as much variation in temperature as the Fort Eustis area but had more variation than the Yuma test site. One peculiarity noted at TTC was that the hottest recorded day (17 January) showed an abnormal series of falls and rises in temperature occurring in the early afternoon. The explanation for this was the cloud cover. Within a 40-minute span, the roof temperature dropped 40°F., rose 28°F., dropped another 44°F., and rose again 40°F. (Figure 7). This variation was reflected throughout the container but to a lesser degree of change. On the same day, the highest amount of total solar radiation was recorded (4,950 langleys). The maximum temperature recorded for the roof was 162°F.; for the ambient air, 95°F.; and for the center of the container, 110°F. A flattening of the temperature curves for the interior, as explained

by Dr. Portig, the meteorologist of TTC, was due possibly to a heat sink effect of the ground. That is, heat being drawn away from the container through the ground prevented a higher rise in temperatures, particularly for the center space of the container.

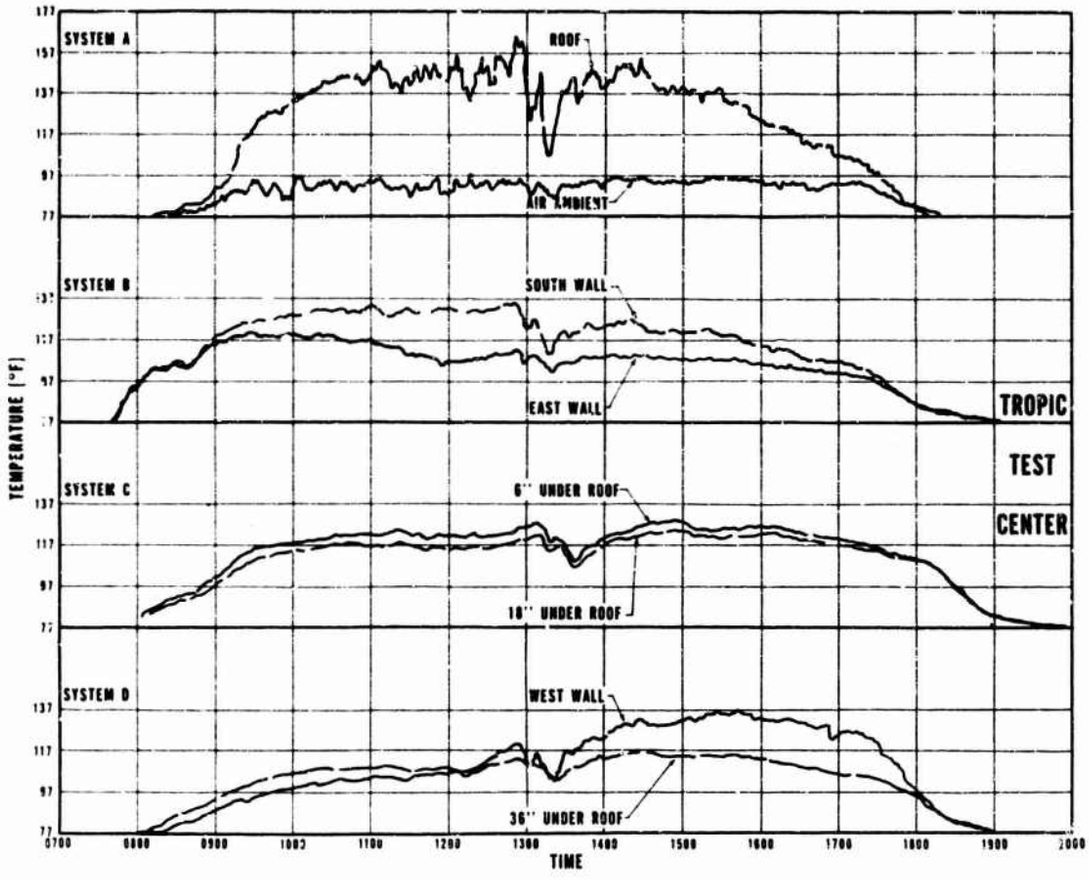


Figure 7. Temperature Data for CONEX, 17 January 1970.

Except for the "double kink" in the curves, the data closely resemble, in form, the data gathered at the Yuma test site. The average air temperature from 1000 to 1700 hours remained at 93°F. The interior temperature remained at about 106°F. from 1000 to 1200 hours, then the temperature began to rise, peaking at 116°F. at 1430 hours. The interior temperatures at 6 inches under the roof, 18 inches under the roof, and 36 inches under the roof followed each other rather closely with little delay in time. A mixing effect due to convection currents and heat transfer may be the cause for this trend.

Table I presents the maximum values of temperatures recorded at the Tropic Test Center, and Table II shows comparative values of recorded and predicted temperatures with percent error at all test sites: Fort

Eustis, Virginia; Yuma, Arizona; and Fort Clayton, Panama Canal Zone. Appendix IV shows typical calculated data for all test areas.

TABLE I
MAXIMUM TEMPERATURES RECORDED FOR EACH CHANNEL
AT TIMES INDICATED FOR TROPIC TEST CENTER
ON 17 JANUARY 1970

Time (Hrs.)	Location/Degrees Fahrenheit							
	AJ1 Ambient Air	AJ2* Roof	BJ1 East Wall	BJ2 South Wall	CJ1 6" Under Roof	CJ2 18" Under Roof	DJ1 West Wall	DJ2 36" Under Roof
0930	92	122	118**	126	115	109	100	93
1000	93	134	118**	127	118	113	97	104
1250	93	162**	111	135**	128**	122**	120	113
1430	93	145	107	122	126	122**	131	116**
1530	95**	135	106	118	126	122**	136**	113

*Refer to Figure 3 for sensor locations.
**Maximum temperature recorded by probe.

TABLE II
COMPARATIVE TABLE OF MEASURED AND CALCULATED VALUES
OF TEMPERATURES FROM PRESENT COMPUTER PROGRAM

Location	Time	Date	Location/Degrees Fahrenheit				Percent of Error
			Max. Ambient (All Day)	Max. Roof (All Day)	Max. Center (Recorded)	Max. Center (Predicted)	
Ft. Eustis, Va.	1330	4 Sep 69	87	155	116	110.9	-4.4
Yuma, Ariz.	1150	1 Oct 69	103	143	117	123.0	+5.1
Ft. Clayton, C. Z.	1430	17 Jan 70	95	162	116	113.8	-1.9

5. Instrument Difficulties. Of the four recorders which were used in the test, two operated with little difficulty and two developed some problems System A operated quite efficiently, but System B developed some problems maintaining correct time. The chart paper of System C would not feed properly and kept slipping, thereby tearing the chart paper. The same problem developed in System D but to a lesser extent. However, at one

point during the test, recorder D would stop about midafternoon, then start up again late at night. Changing the batteries solved the problem. Also, keeping the connectors dry during rainstorms was important; otherwise, sporadic marks would appear on the chart. It is emphasized that very careful attention be paid to the loading of the chart paper onto the recorder.

6. Weather. The weather conditions in the Canal Zone were both wet and dry, but hot (Figures 8 and 9). For a dry season, the Canal Zone experienced unusual rainfall during the tests.

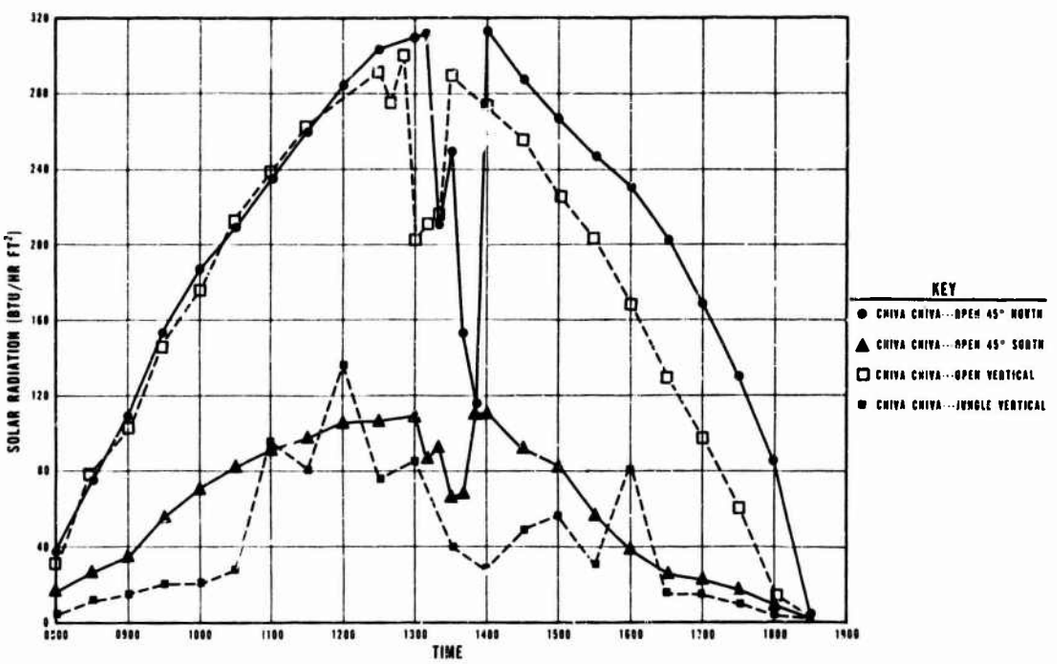


Figure 8. Weather Data Solar Radiation, 17 January 1970.

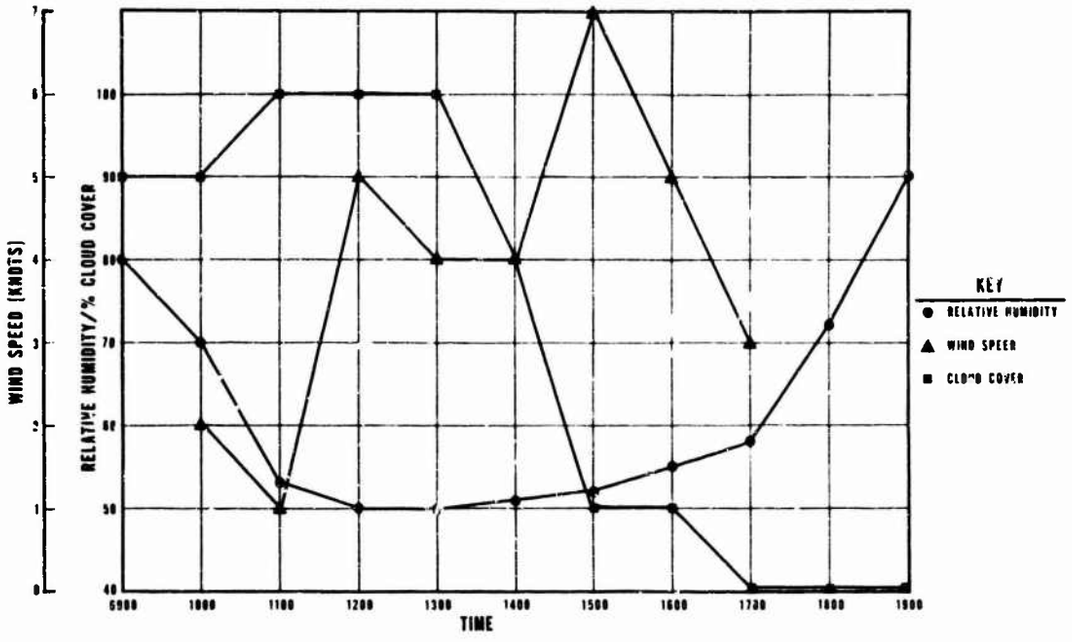


Figure 9. Weather Data Wind Speed, Relative Humidity, and Percent Cloud Cover, 17 January 1970.

APPENDIX I

COMPUTER PROGRAM LISTING FOR PREDICTING MAXIMUM TEMPERATURES INSIDE CLOSED CONTAINERS

TEMDAT

```
100 FILES CONTFI;COEFFI;MONTFI;FOREFI;FORDFI;TEMPOR
110 DIM A$(110),K(110),C(110)
120 PRINT "NEW DATA (YES=1,NO=0)";
130 INPUT W1
140 IF W1=0 THEN 240
150 PRINT
160 PRINT "GIVE TIME ZONE(1-12), AND LOCATION";
170 INPUT T1,B$
180 PRINT "GIVE NORTH(1) OR SOUTH(0) LAT AND LONG IN DEG,MIN,AND SEC"
190 INPUT P1,L1,L2,L3,L7,L8,L9
200 PRINT "GIVE DATE (E.G. 12,25,66)";
210 INPUT Y6,Y7,Y8
220 PRINT "GIVE TIME SPAN BEGIN(HR,MIN),END(HR,MIN),INCREMENT(MIN)"
230 INPUT A1,A2,Z1,Z2,X
240 PRINT
244 PRINT "WHAT WAS THE MAXIMUM TEMPERATURE OF THE DAY";
246 INPUT T
248 PRINT
250 PRINT "DATA BY MATERIAL (0), OR MANUFACTURER (1)";
260 INPUT R
270 IF R=0 THEN 400
280 PRINT "WHAT IS THE MANUFACTURER";
290 INPUT A$
300 FOR N2=1 TO 24
310 READ #1,A$(N2),K(N2)
320 IF A$(N2)=A$ THEN 370
330 NEXT N2
340 PRINT A$;" NOT LISTED"
350 SET#1,1
360 GOTO 280
370 LET R=K(N2)
380 LET A$="NONE"
390 GOTO 430
400 PRINT "WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)"
410 INPUT A$,L
420 GOTO 450
430 LET H(0)=1.65
440 LET H(1)=6
450 IF A$="NONE" THEN 560
460 SET#2,1
470 FOR N2=1 TO 110
480 READ #2,A$(N2),K(N2),C(N2)
490 IF A$(N2)=A$ THEN 530
500 NEXT N2
510 PRINT A$;" NOT LISTED"
520 GOTO 400
530 LET L=L/12
540 LET R=R+L/K(N2)
550 GOTO 400
560 LET R3=1/R
```

TEMDAT CONTINUED

```
570 LET R4=1/R3+1/1.65+1/6
580 LET U=1/R4
590 LET F=.225*U+.0025
600 LET A7=100
610 PRINT
620 PRINT
630 PRINT
640 PRINT
650 SCRATCH :6
660 IF W1=0 THEN 690
670 WRITE:6,T;F;U;W1;T1;B$;P1;L1;L2;L3;L7;L8;L9;Y6;Y7;Y8;A1;A2;Z1;Z2;X
680 CHAIN SOLRAD
690 WRITE :6,T;F;U;W1
700 CHAIN SOLRAD
710 END
```

SOLRAD

```
100 FILES CONTFI,COEFFI,MONTFI,FOREFI,FORDFI,TEMPOR
110 DIM Q(12),E(10,10),D(10,10)
120 REM MAIN PROGRAM CALCULATES SOLAR AZIMUTHS AND ELEVATIONS
130 FOR W=1 TO 12
140 READ :3,Q(W)
150 NEXT W
160 FOR I=1 TO 2 STEP 1
170 FOR J=1 TO 6 STEP 1
180 READ :4,E(I,J)
190 NEXT J
200 NEXT I
210 FOR I=1 TO 2 STEP 1
220 FOR J= 1 TO 6 STEP 1
230 READ :5,D(I,J)
240 NEXT J
250 NEXT I
260 LET R=57.29577951
270 LET Y1=64
280 LET S1=0
290 LET N1=0
300 LET B9=1
310 READ H5,H9,C5,C9
320 READ P1,L1,L2,L3,L7,L8,L9
330 READ T1,B$
340 READ Y6,Y7,Y8
350 READ A1,A2,Z1,Z2,X
360 READ B8,P,B
370 READ :6,T,F,U,W1
380 IF W1=0 THEN 410
390 SET :6,5
400 READ:6,T1,B$,P1,L1,L2,L3,L7,L8,L9,Y6,Y7,Y8,A1,A2,Z1,Z2,X
410 LET Y6=Y5=Y6
420 PRINT
430 PRINT
440 PRINT
450 LET D8=0
460 LET Y6=Y5=Y6
470 LET Y6=Y6-1
480 IF Y6=0 THEN 510
490 LET D8=D8+Q(Y6)
500 GOTO 470
510 LET D8=D8+Y7
520 LET L=(L1+(L2+L3/60)/60)/R
530 LET J8=Y8-10*INT(Y8/10)
540 LET L$="NORTH"
550 IF P1>=0 THEN 580
560 LET L=-L
570 LET L$="SOUTH"
580 LET M=(L7+(L8+L9/60)/60)/15
590 LET M$="WEST"
```

SOLRAD CONTINUED

```
600 IF T1>=0 THEN 630
610 LET M=-M
620 LET M$="EAST"
630 LET W$="DATA FOR"
640 LET X$="LAT"
650 LET Y$="LONG"
660 LET Z$="DATE:"
670 PRINT USING 1900,W$,B$,Z$,Y5,"/",Y7,"/",Y8
680 PRINT USING 1910,X$,L1,L2,L3,L$,Y$,L7,L8,L9,M$
690 PRINT
700 PRINT
710 PRINT
720 PRINT "SOLAR RADIATION DATA (BTU/HR/SQ.FT.)";TAB(50);"TEMPERATURE D
730 PRINT USING 740
740:TIME            TOT.   H/TOT.   INPUT              AMBIENT    INTERIOR
750 PRINT
760 LET M1=12+M-T1
770 LET Y9=Y1-Y8
780 IF Y9<0 THEN 810
790 IFY9=0 THEN 860
800 IF Y9>0 THEN900
810 LET Y1=G=Y1
820 GO SUB 1340
830 LET S1=S1+366-FNL(Y1)
840 LET Y1=Y1+1
850 GO TO 770
860 LET Y8=G=Y8
870 GO SUB 1340
880 LET Q(2)=29-FNL(Y8)
890 GO TO 950
900 LET Y1=Y1-1
910 LET Y1=G=Y1
920 GO SUB 1340
930 LET S1=S1-366+FNL(Y1)
940 GO TO 770
950 LET A4=A3=60*A1+A2
960 LET Z3=60*Z1+Z2
970 IF X>0 THEN 990
980 LET X=1
990 LET D9=D8+T1/24+S1
1000 LET A5=A4/60
1010 GO SUB 1420
1020 LET M2=A5+E1-M1
1030 LET D2 =SIN(D1)
1040 LET H=SIN(L)*SIN(D1)+COS(L)*COS(D1)*COS(M2*15/R)
1050 LET H1=H/SQR(1-H↑2)
1060 LET H2=ATN(H1)
1070 LET H3=COS(H2)
1080LET H2=H2*R
1090 LET C=(SIN(D1)-SIN(L)*H)/(COS(L)*H3)
```

SOLRAD CONTINUED

```
1100 LET C1=SQR(1-C↑2)/C
1110 LET C2=ATN(C1)*R
1120 IF C1>=0 THEN 1140
1130 LET C2=C2+180
1140 IF M2<=0 THEN 1160
1150 LET C2=360-C2
1160 LET A6=A3/60
1170 LET Z9=A3-Z3
1180 IF Z9>0 THEN 1820
1190 LET A8=A3/60
1200 LET A9=A8-INT(A8)
1210 LET T9 =100*INT(A8)+INT(60*A9+.0001)
1220 LET A7=(1-COS(T9*26.1799E-4))/2
1230 LET A7=30*A7+70
1240 IF B9>0 THEN 1580
1250 LET A4=A3=A3+X
1260 GO TO 1000
1270 DATA 0,90,0,360
1280 DATA 1,32,45,9,114,41,30
1290 DATA 7,"YUMA, ARIZONA"
1300 DATA 10,1,69
1310 DATA 6,0,18,0,60
1320 DATA 0,270,0
1330 RETURN
1340 DEF FNL(G)=4*(G/4-INT(G/4))
1350 LET G1=1-FNL(G)
1360 IF G1>0 THEN 1390
1370 DEF FNL(G)=1
1380 GO TO 1400
1390 DEF FNL(G)=0
1400 RETURN
1410 REM SUBPROGRAM CALCULATES THE REQUIRED FOURIER SERIES
1420 LET Y=6.2831853*(D9+A5/24)/365.2422
1430 LET E(1,0)=.783693
1440 LET D(1,0)=.380278
1450 LET Z=1
1460 LET E1=E(1,0)
1470 LET D1=D(1,0)
1480 FOR N=1 TO 5
1490 LET Y=Z*Y
1500 LET E1=E1+E(1,N)*COS(Y)+E(2,N)*SIN(Y)
1510 LET D1=D1+D(1,N)*COS(Y)+D(2,N)*SIN(Y)
1520 LET Z=Z+1
1530 NEXT N
1540 LET E1=(E1+E(1,6)*COS(Z*Y))/3600
1550 LET D1=(D1+D(1,6)*COS(Z*Y))/R
1560 RETURN
1570 REM SUBPROGRAM CALCULATES SOLAR FRACTIONS DUE TO WALL INCLINATIONS
1580 LET K=H*SIN(B/R)+H3*COS(B/R)*COS((C2-P)/R)
1590 IF K4>=0 THEN 1620
```

SOLRAD CONTINUED

```
1600 LET K5=0
1610 GO TO 1630
1620 LET K5=INT(K4*10↑6+.5)/10↑6
1630 GO SUB 1740
1640 LET A7=40*SIN((3.14159*(A5-6)/12))+(T-40)
1650 LET S9=K5*FNJ(H2)+FNI(H2)
1660 LET O9=H*FNJ(H2)+FNI(H2)
1670 LET T1=S9+O9
1680 LET S1=FNJ(H2)+FNI(H2)
1690 LET R1=(((O9)+(1.714E-9)*(A7+459.4)↑4)/(3.428E-9))↑.25
1700 PRINT USING 1710,T9,S1,O9*100/T1,F*T1,A7,F*T1/3+A7
1710:####              ###    ##.##    ###.#            ###.#       ###.#
1720 GO TO 1250
1730 REM SUBPROGRAM CALCULATES THE INCIDENT SOLAR RADIATION
1740 LET A1=B8
1750 IF A1>0 THEN 1790
1760 DEF FNJ(H)=296*(1-EXP(-.054*H))
1770 DEF FNI(H)=36*(1-EXP(-.023*H))
1780 GO TO 1810
1790 DEF FNJ(H)=215*(1-EXP(-.033*H))
1800 DEF FNI(H)=53*(1-EXP(-.02*H))
1810 RETURN
1820 PRINT
1830 PRINT
1840 PRINT
1850 PRINT "ANOTHER PROBLEM (YES=1,NO=0)";
1860 INPUT R
1870 IF R=1 THEN 1890
1880 END
1890 CHAIN TEMDAT
1900:"        ""                    "            "      " ##'##'##
1910:"   "## ## ## "      "    "    "### ## ## "    "
```

EXTREME TEMPERATURES IN STORAGE OR TRANSIT
OBSERVED OR REPORTED IN LITERATURE*

Source	Type Storage or Transit Space	Location	Max. Temp. of Air at Top of Space (°F.)	Max. Temp. of Air in Most Critical Carton (°F.)	Max. or Hrly. Food Temp. (Not Necessarily Concurrent with Carton Air Temp. Cond. As Indicated) (°F.)	Max. Temp. of Outside Air (°F.)
Field Tests	Dump Covered with Tight Tarp.	Blythe, Calif. and Indian Bay, Fla.	150-160	126 (4 Hrs. Over 120).	115 Max. in Food at Top of Stack.	113
Questionnaires	Dump Covered with Tight Tarp.	Marianas Is., S.W. Pacific	---	125 (5 Hrs. Over 120).	110 in Food at Top of Stack at 1345 Hrs.	89
Questionnaires	Warehouse, Cement, and Asbestos Roof.	Agra, India	---	107	98 in Food at Top of Stack at 1500 Hrs.	110
	Warehouse, Corrugated Iron Roof.	Pelilieu, Caroline Is., S.W. Pacific	---	107	100 in Food at Center of Stack at 1100 Hrs.	87
Field Tests	Domestic Army Warehouse, Wood Frame and Walls, Asphalt Roof.	Ft. Worth, Tex.	111 (11' From Floor) and 5 From Roof.	---	---	104
Field Tests	Tents, Closed.	Ft. Lee, Va.	156 (9' From Ground and 1-1/2' From Canvas Roof).	---	---	94
Field Tests	Moving Boxcars Loaded to 5' with Cartons of Dried Fruit.	Near Needles, Calif.	134	102	---	About 111
	Stationary Boxcars Loaded to 5' with Cartons Containing Six #10 Cans of String Beans.	Yuma, Ariz.	152	119	113 Max.	111
Literature*	Shipholds.	Marcus Is., S.W. Pacific	110 Upper 'Tween Decks	---	---	102 (At Time of Hold Temp. Max.)

*Recent and Current Work on High Temperatures in Storage and Transportation, W. L. Porter (Reprinted from Proceedings of of the Seventh Annual Meeting, published by the Research and Development Associates, Food and Container Institute, Inc.)

APPENDIX III

EXCERPT FROM ARMY REGULATION 705-15, CHANGE 1, 14 OCTOBER 1963

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7.1 Storage and transit conditions. All military materiel must be capable of safe storage and transportation without permanent impairment of its capabilities from the effects of extreme conditions. Materiel destined for high temperature, low temperature, or extreme low temperature storage or air transit must be capable of withstanding those conditions as defined below. Storage extremes are given for temperature, humidity, and pressure only. Values for other elements are the same as for intermediate climatic conditions.

a. High temperature storage. Air temperatures 155°F. (68.3°C.) for periods up to 4 hours daily without benefit of solar radiation and with negligible air movement. Absolute humidity 13 grains/-ft^3. Materiel temperature under these conditions depends on thermal capacity and mass of stored items.

b. Low temperature storage. Air temperatures -65°F. (-53.9°C.) for 12 hours without benefit of solar radiation and with negligible air movement.

c. Extreme low temperature storage. Air temperature -80°F. (-62.2°C.) for 3 days without benefit of solar radiation and negligible air movement.

d. Air transit conditions. All military materiel shipped by air (to be specified in QMR) will also take into account air pressure at 40,000 feet which is as follows: (5.00) inches of mercury or (2.47) pounds per square inch.

* * * * * * *

APPENDIX IV

COMPUTER PRINTOUT, CALCULATED VALUES OF TEMPERATURE FROM COMPUTER PROGRAM FOR FORT EUSTIS, YUMA PROVING GROUND, AND TROPIC TEST CENTER

```
TEMDAT     15:18    04 THU 02/05/70

NEW DATA (YES=1,NO=0)? 1

GIVE TIME ZONE(1-12), AND LOCATION? 5,"FORT EUSTIS"
GIVE NORTH(1) OR SOUTH(0) LAT AND LONG IN DEG,MIN,AND SEC
? 1,37,7,0,76,35,0
GIVE DATE (E.G. 12,25,66)? 9,4,69
GIVE TIME SPAN BEGIN(HR,MIN),END(HR,MIN),INCREMENT(MIN)
? 6,0,19,0,60

WHAT WAS THE MAXIMUM TEMPERATURE OF THE DAY? 87

DATA BY MATERIAL (0), OR MANUFACTURER (1)? 0
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? "1.5%C STEEL",.125
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? NONE,1
```

DATA FOR FORT EUSTIS DATE: 9/ 4/ 69
LAT 37 7 0 NORTH LONG 76 35 0 WEST

SOLAR RADIATION DATA (BTU/HR/SQ.FT.) TIME	TOT.	H/TOT.	INPUT	TEMPERATURE DATA AMBIENT	INTERIOR
600	20	56.52	1.8	47.0	47.6
700	95	71.75	13.9	57.4	62.0
800	140	78.04	29.0	67.0	76.7
900	180	81.24	43.9	75.3	89.9
1000	203	82.96	56.1	81.6	100.3
1100	215	83.82	64.3	85.6	107.1
1200	220	84.10	67.5	87.0	109.5
1300	216	70.13	77.8	85.6	111.6
1400	205	58.39	81.8	81.6	108.9
1500	184	48.20	77.3	75.3	101.0
1600	152	38.48	63.5	67.0	88.2
1700	103	28.30	40.7	57.4	70.9
1800	31	16.45	11.1	47.0	50.7
1900	-70	.76	-20.3	36.6	29.9

```
ANOTHER PROBLEM (YES=1,NO=0)? 0

USED     51.17 UNITS
BYE
*** OFF AT 15:33   ELAPSED TERMINAL TIME =      15 MIN.
```

```
TEMDAT     11:08    04 FRI 02/06/70

NEW DATA (YES=1,NO=0)? 1

GIVE TIME ZONE(1-12), AND LOCATION? 7,"YUMA,ARIZONA"
GIVE NORTH(1) OR SOUTH(0) LAT AND LONG IN DEG,MIN,AND SEC
? 1,32,45,0,114,41,0
GIVE DATE (E.G. 12,25,66)? 10,1,69
GIVE TIME SPAN BEGIN(HR,MIN),END(HR,MIN),INCREMENT(MIN)
? 6,0,19,0,60

WHAT WAS THE MAXIMUM TEMPERATURE OF THE DAY? 104

DATA BY MATERIAL (0), OR MANUFACTURER (1)? 0
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? "1.5%C STEEL",.125
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? NONE,2
R
```

DATA FOR YUMA,ARIZONA DATE: 10/ 1/ 69
LAT 32 45 0 NORTH LONG 114 41 0 WEST

TIME	SOLAR RADIATION DATA (BTU/HR/SQ.FT.) TOT.	H/TOT.	INPUT	TEMPERATURE DATA AMBIENT	INTERIOR
600	-76	-.87	-2.7	64.0	63.1
700	33	59.92	3.2	74.4	75.4
800	105	73.22	16.4	84.0	89.3
900	153	78.73	31.6	92.3	102.8
1000	183	81.48	45.3	98.6	113.7
1100	201	82.88	55.5	102.6	121.1
1200	210	83.47	60.7	104.0	124.2
1300	209	74.26	67.8	102.6	125.2
1400	200	60.95	74.0	98.6	123.3
1500	180	49.76	71.6	92.3	116.1
1600	148	39.19	59.5	84.0	103.8
1700	98	28.10	37.7	74.4	86.9
1800	22	15.03	7.6	64.0	66.5
1900	-92	-2.67	-26.2	53.6	44.9

```
ANOTHER PROBLEM (YES=1,NO=0)? 1
```

```
TEMDAT     12:44    04 WED 02/11/70

NEW DATA (YES=1,NO=0)? 1

GIVE TIME ZONE(1-12), AND LOCATION? 5,FORT ----"FORT CLAYTON"
GIVE NORTH(1) OR SOUTH(0) LAT AND LONG IN DEG,MIN,AND SEC
? 1,9,0,0,79,35,0
GIVE DATE (E.G. 12,25,66)? 1,17,70
GIVE TIME SPAN BEGIN(HR,MIN),END(HR,MIN),INCREMENT(MIN)
? 6,0,19,0,60

WHAT WAS THE MAXIMUM TEMPERATURE OF THE DAY? 95

DATA BY MATERIAL (0), OR MANUFACTURER (1)? 0
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? "1.5%C STEEL",.125
WHAT IS THE MATERIAL (,) AND ITS THICKNESS (INCHES)
? "NONE",7
```

DATA FOR F"FORT CLAYTON" DATE: 1/ 17/ 70
LAT 9 0 0 NORTH LONG 79 35 0 WEST

TIME	SOLAR RADIATION DATA (BTU/HR/SQ.FT.) TOT.	H/TOT.	INPUT	TEMPERATURE DATA AMBIENT	INTERIOR
600	-94	-30.36	-2.6	55.0	54.1
700	30	59.34	3.0	65.4	66.3
800	111	73.91	17.8	75.0	80.9
900	162	79.57	35.1	83.3	95.0
1000	194	82.31	50.9	89.6	106.6
1100	213	83.67	62.8	93.6	114.6
1200	222	84.24	69.2	95.0	118.1
1300	222	76.70	75.9	93.6	118.9
1400	213	64.23	81.6	89.6	116.8
1500	193	53.35	78.3	83.3	109.4
1600	161	42.70	65.0	75.0	96.7
1700	110	31.09	41.7	65.4	79.3
1800	29	16.84	9.8	55.0	58.3
1900	-97	-3.49	-25.9	44.6	36.0

```
ANOTHER PROBLEM (YES=1,NO=0)? 0

USED     38.67 UNITS
```

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Transportation Engineering Agency Military Traffic Management and Terminal Service Fort Eustis, Virginia 23604	2a. REPORT SECURITY CLASSIFICATION Unclassified. 2b. GROUP

3. REPORT TITLE

PREDICTING HIGH TEMPERATURES INSIDE CARGO CONTAINERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

John H. Grier and Victor K. Chan, 1LT, TC

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1970	24	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	USATEA REPORT 70-8
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This report summarizes the work in connection with a study on predicting high temperature inside cargo containers and presents, in detail, information on tests conducted at ~~the Tropic~~ Test Center in the Panama Canal Zone. Included are meteorological data provided by the Tropic Test Center, temperature values recorded both on the surface and inside a CONEX container, and photographs of the test area. A comparison is made between recorded values and temperatures calculated by a computer program previously developed by the U.S. Army Transportation Engineering Agency. Computer printouts are included as appendixes.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Temperature Solar Radiation						